Remote sensing of plants: state-of-the-art and applications to crop phenotyping

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Blue River Technology
ARPA-E workshop, Chicago
June 18, 2014

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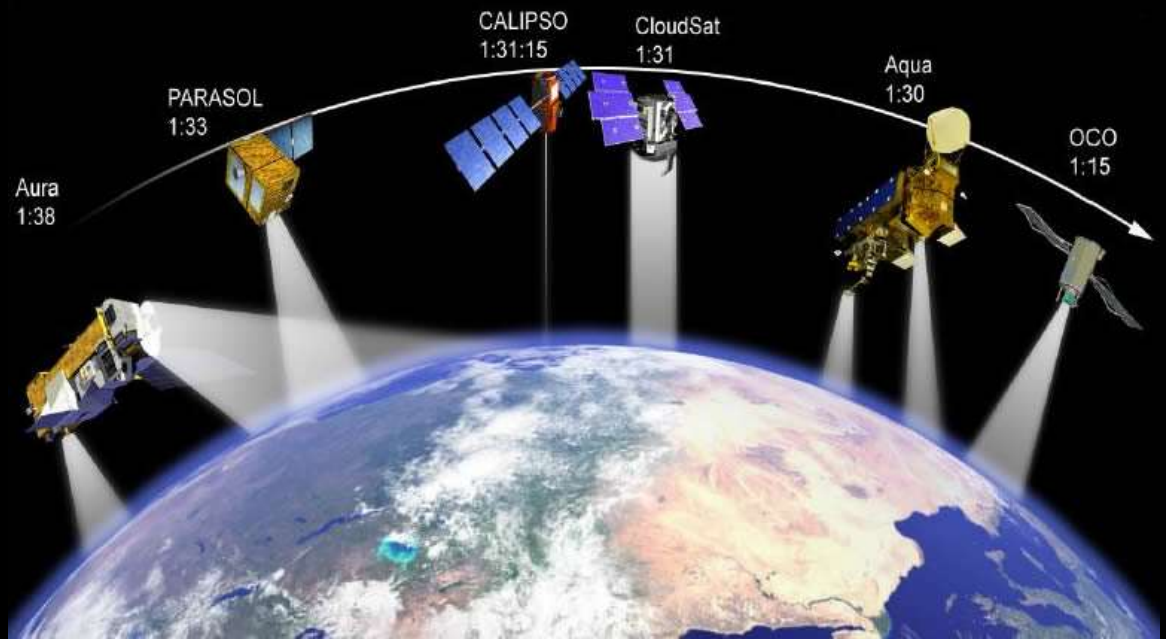
Overview

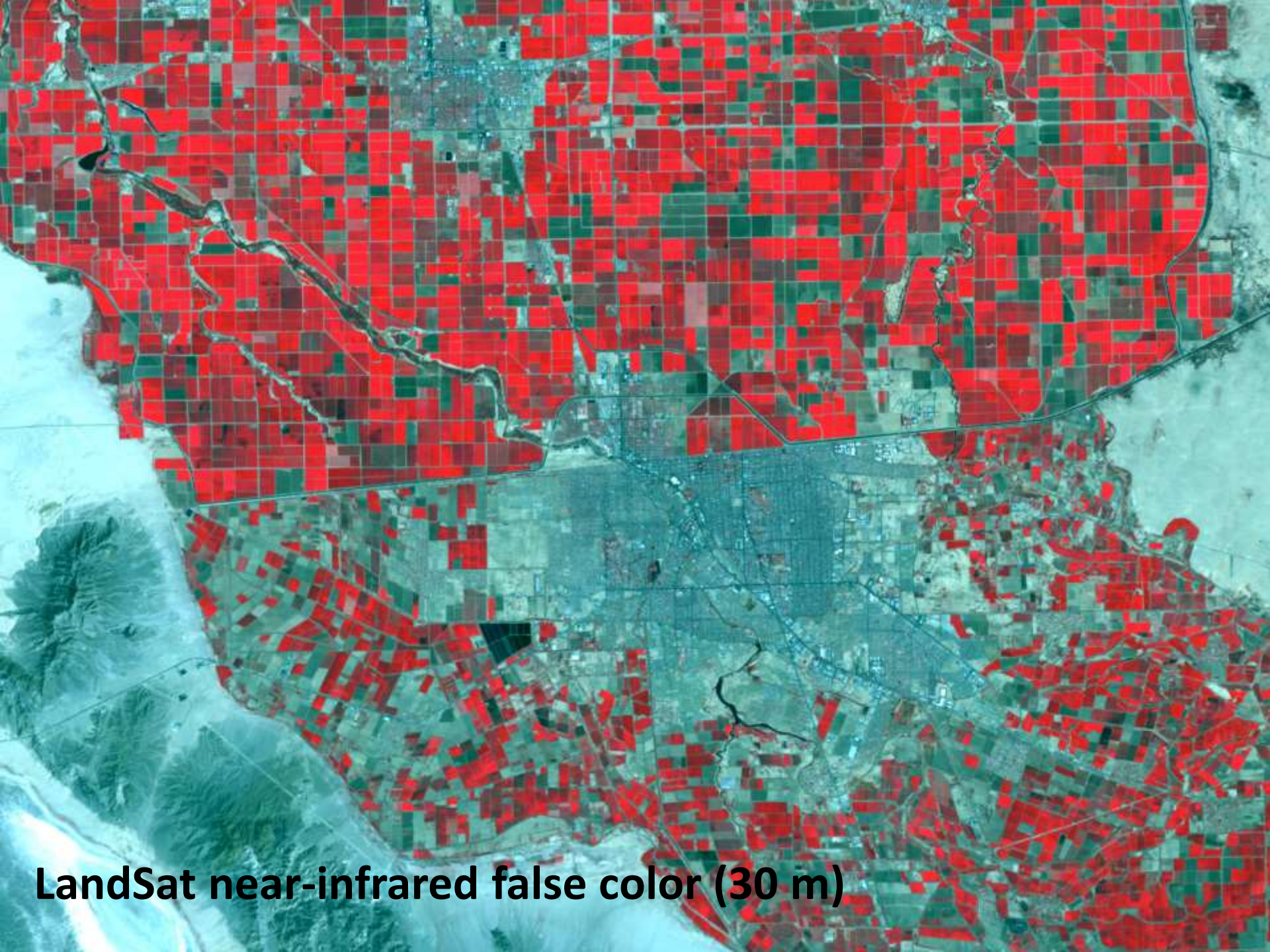
- Plant remote sensing: state of the art
- Spectral fingerprinting & hyperspectral imaging
- Measuring crop phenotypic traits (eg biomass)
- Wish list for future technologies
- Phenotyping prototypes

Remote sensing of plants

- What is remote sensing?

"Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to in situ observation." -*Wiki*





LandSat near-infrared false color (30 m)

Common terrestrial remote sensing technologies

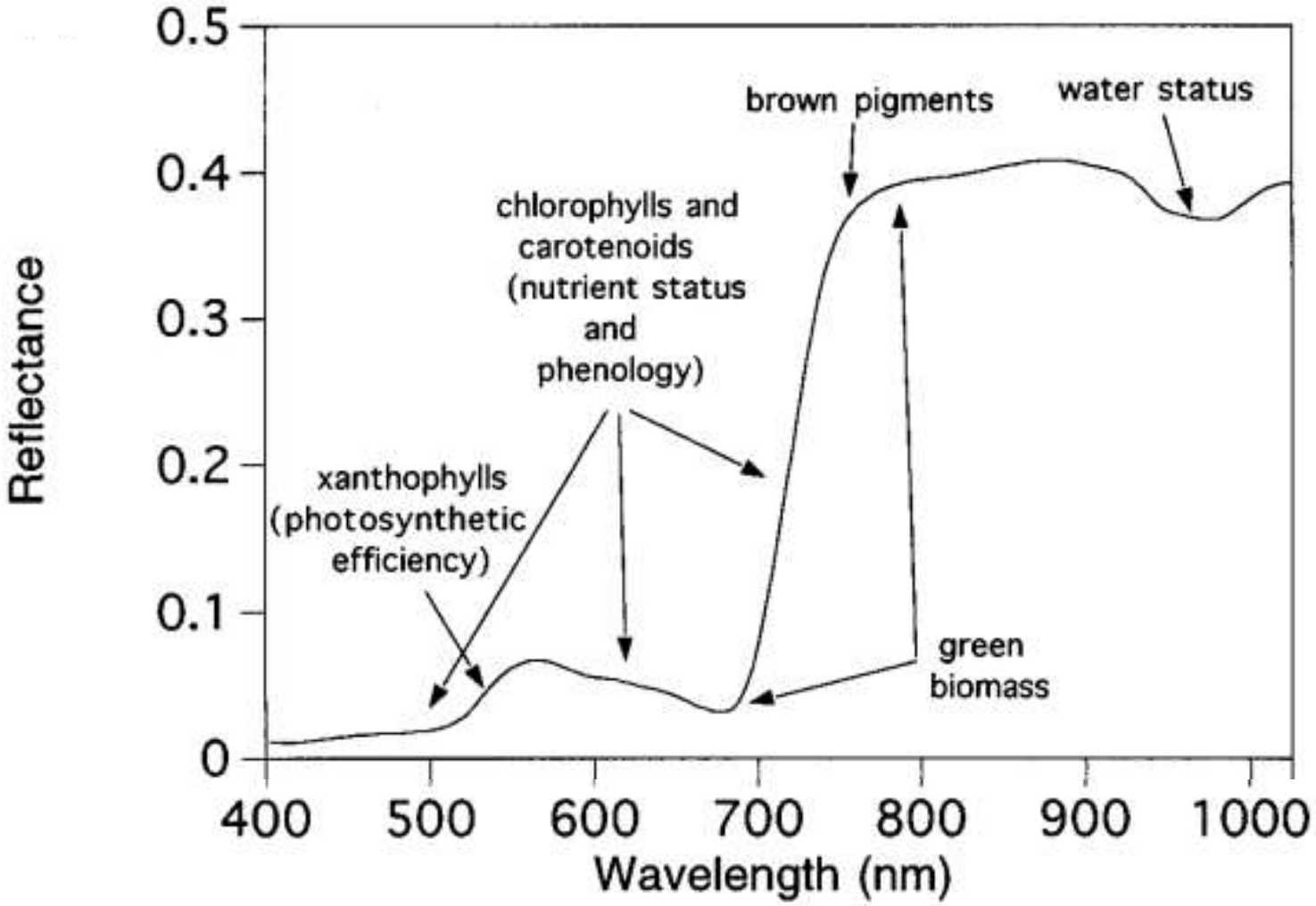
- Passive sensors

  Airborne and spaceborne imaging spectrometers (eg LandSat, AVIRIS, Hyperion, CAO)

  – UV
  – Visible
  – Near- and short-wave infrared (NIR, SWIR)
  – Long-wave infrared (thermal)
  – Handheld spectrometer (“proximal” sensing)

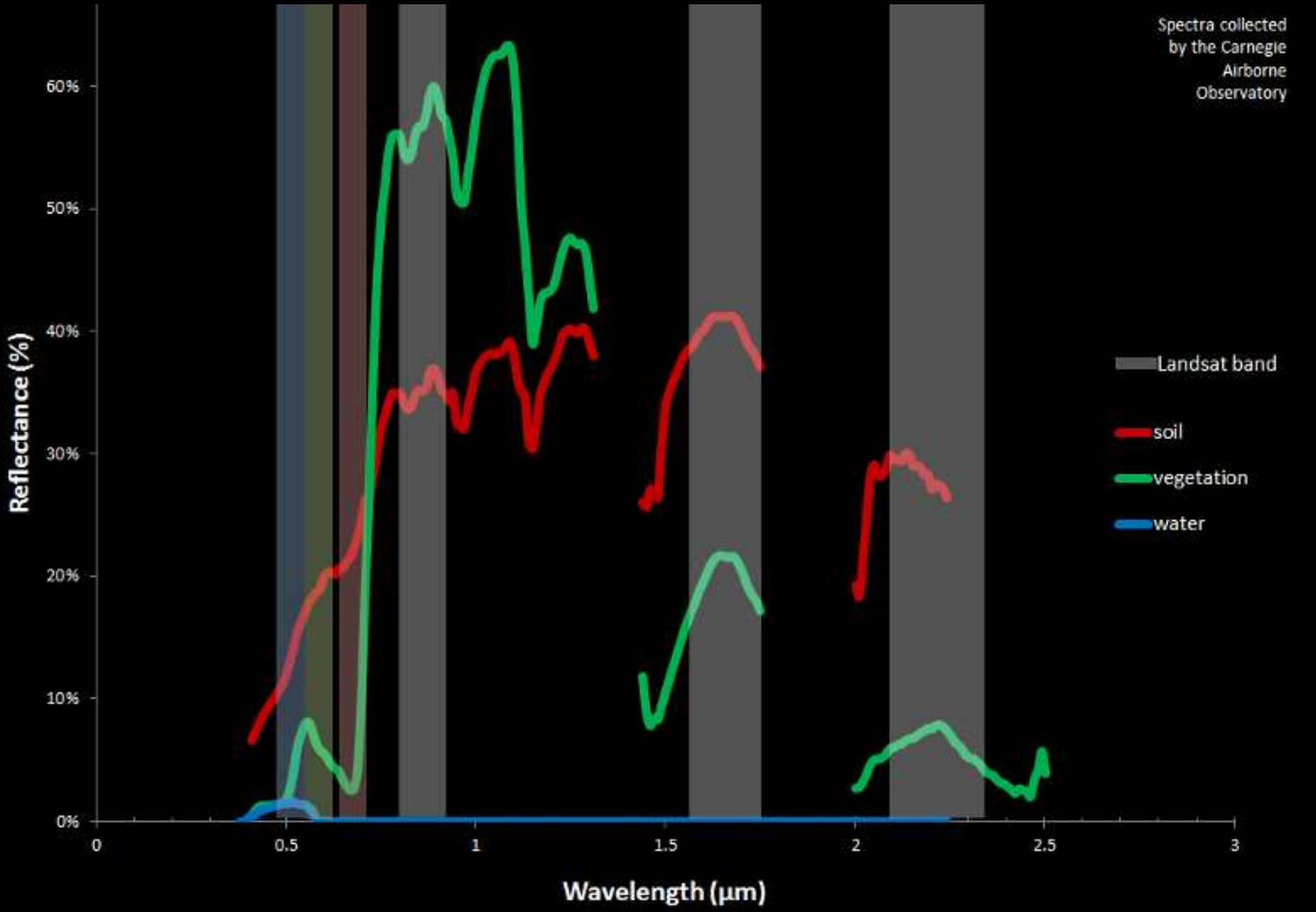
- Active sensors
  – LiDAR
  – Radar

Measuring plant chemistry using reflectance spectra



Penulas & Fillela, TiPS, 1998

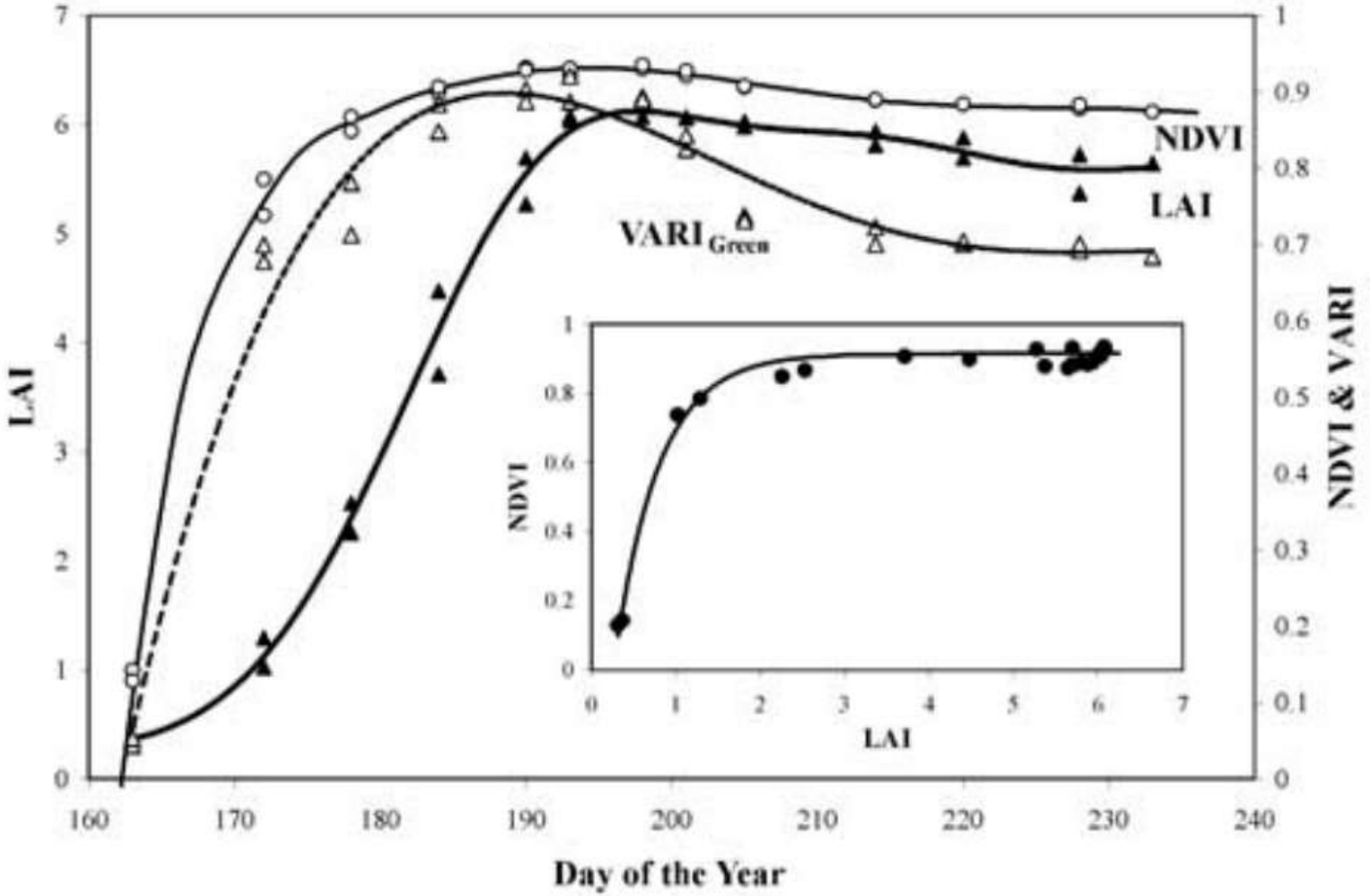
Comparison of multi- & hyper- spectral reflectance measurements



Advantages of remotely sensing plants

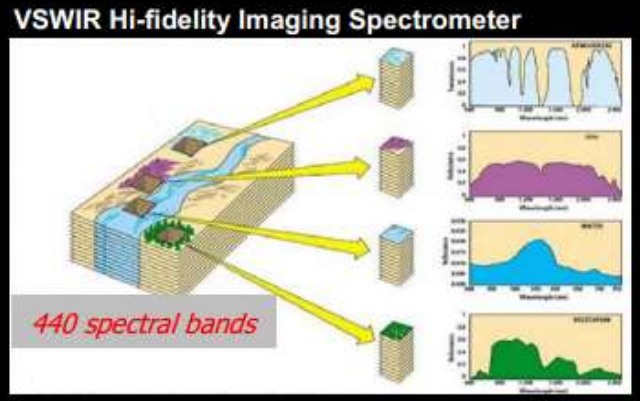
- Non-destructive
- Can cover large areas
- Repeatability
- Detection of non-visible wavelengths

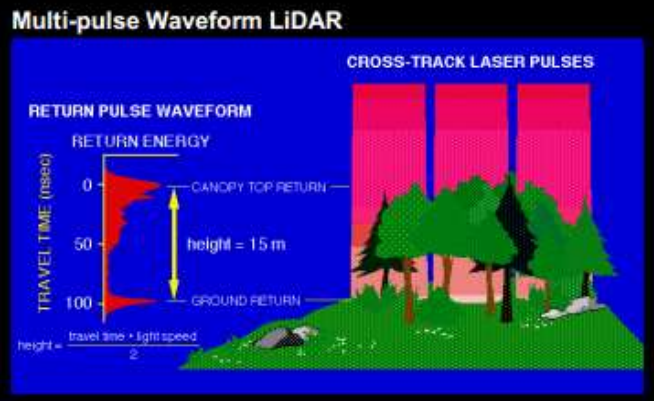
Measuring leaf area in corn using near-infrared

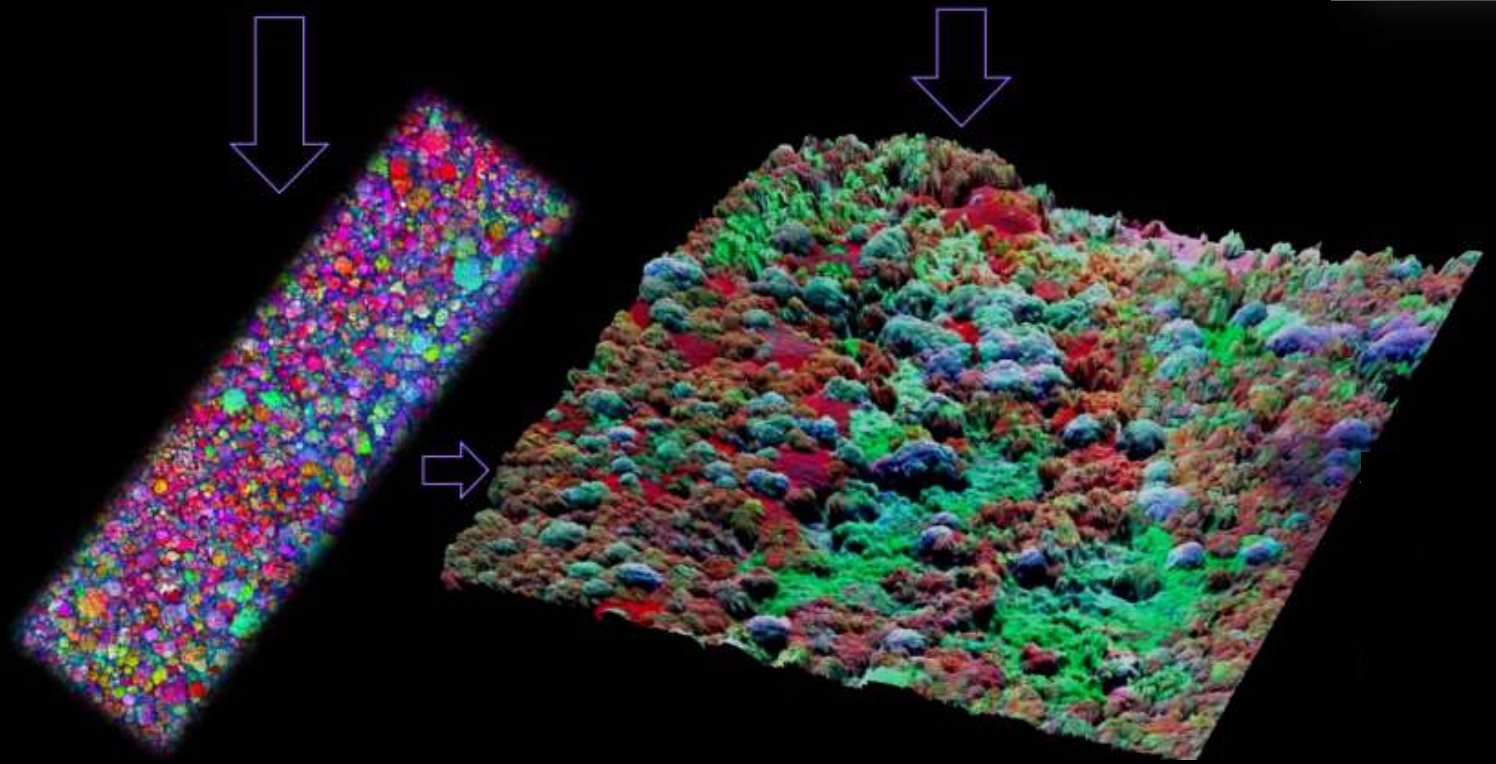


Gitelson et al., GRL, 2003

Airborne hyperspectral imaging + LiDAR: mapping leaf chemistry in 3D





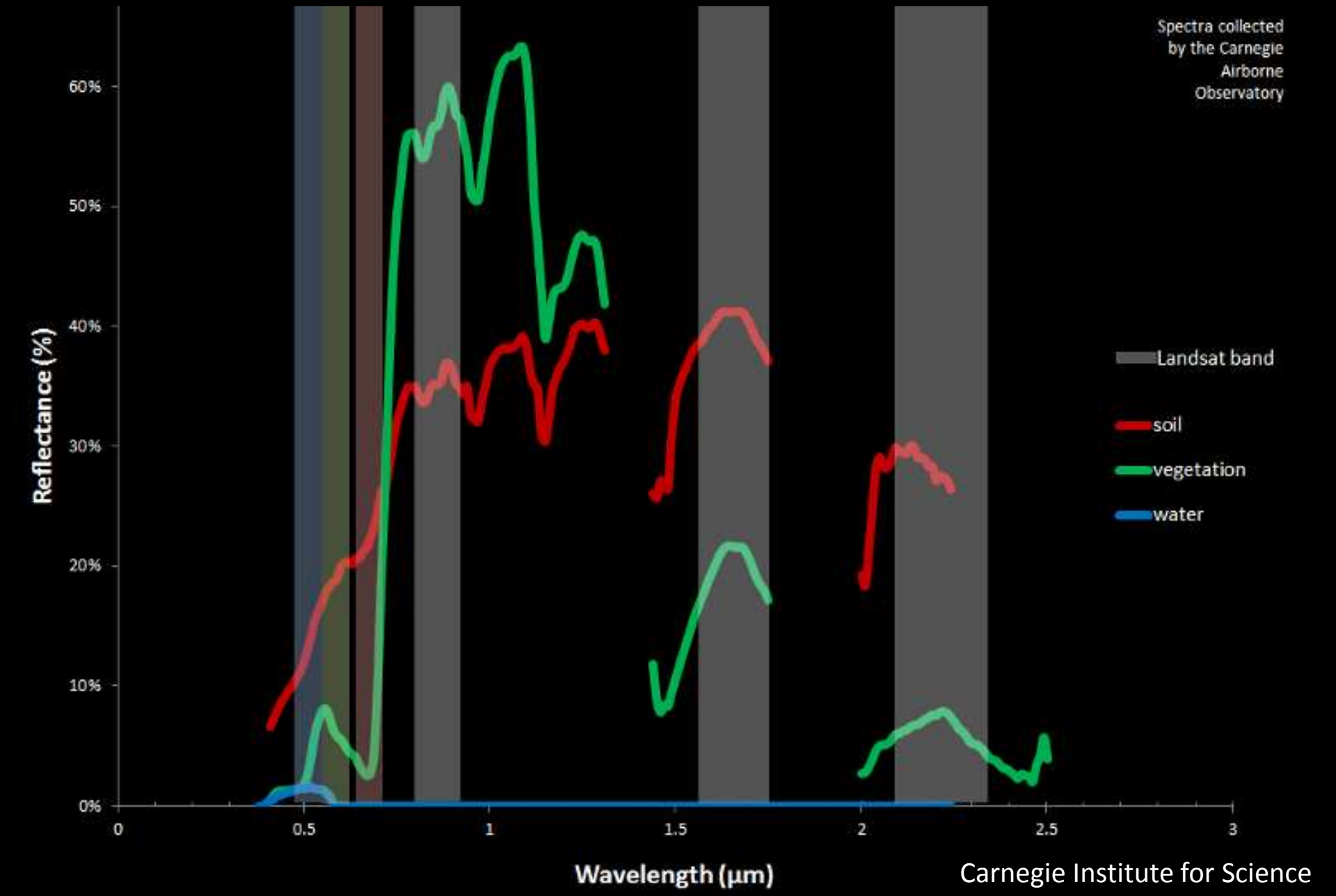


Asner et al., RSE, 2012

Airborne hyperspectral imaging and LiDAR: mapping leaf chemistry in 3D

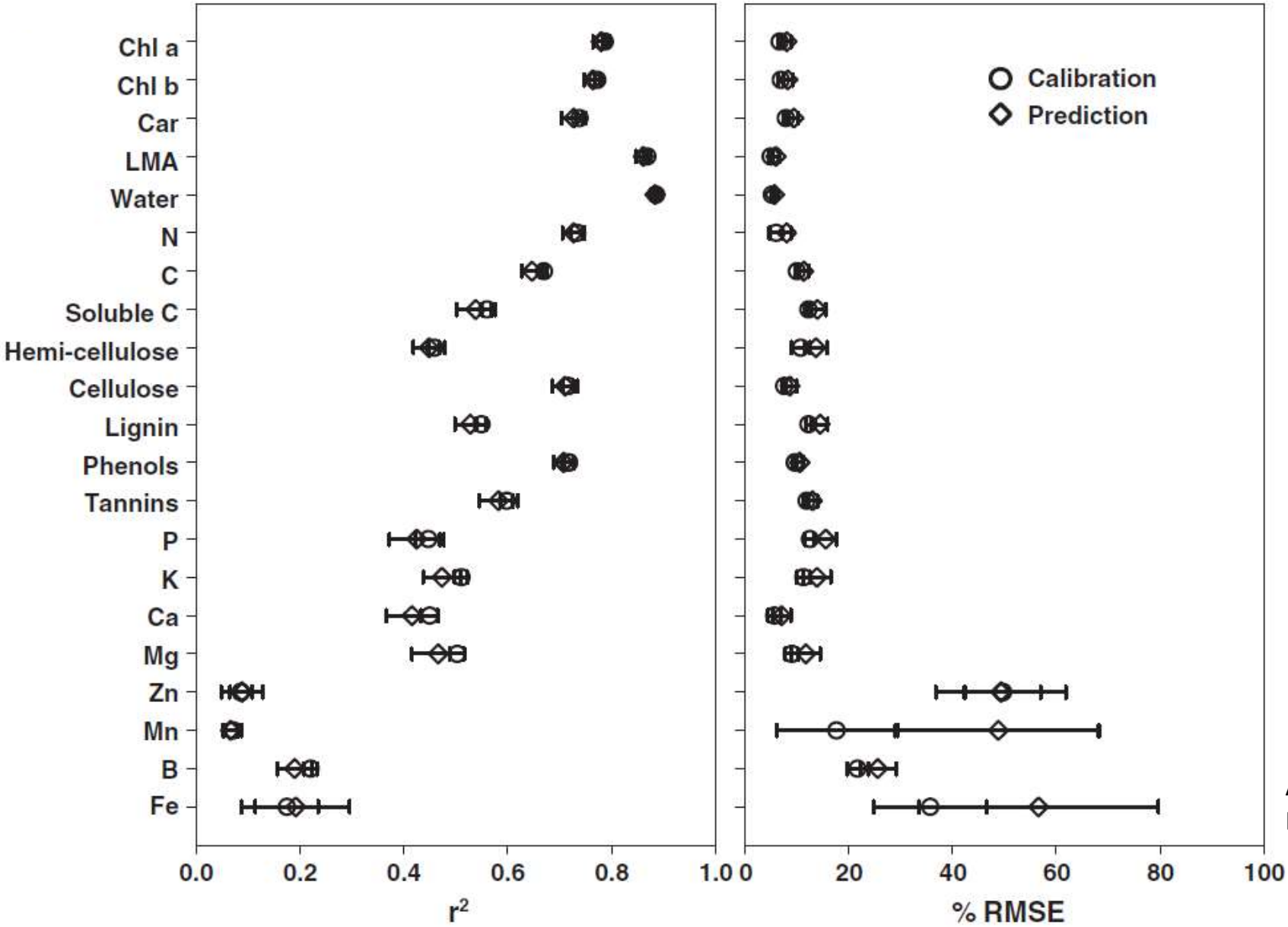
Carnegie Institute for Science

Comparison of multi- & hyper- spectral reflectance measurements



Carnegie Institute for Science

20 leaf chemical measured in the lab and correlated to field hyperspectral measurements

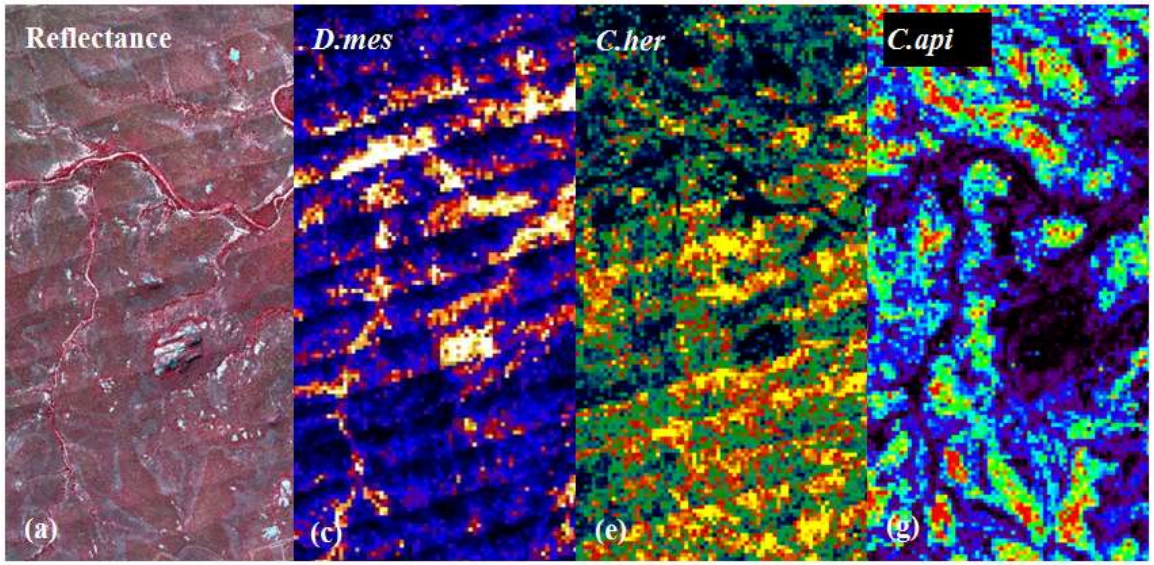


Asner et al., RSE, 2011

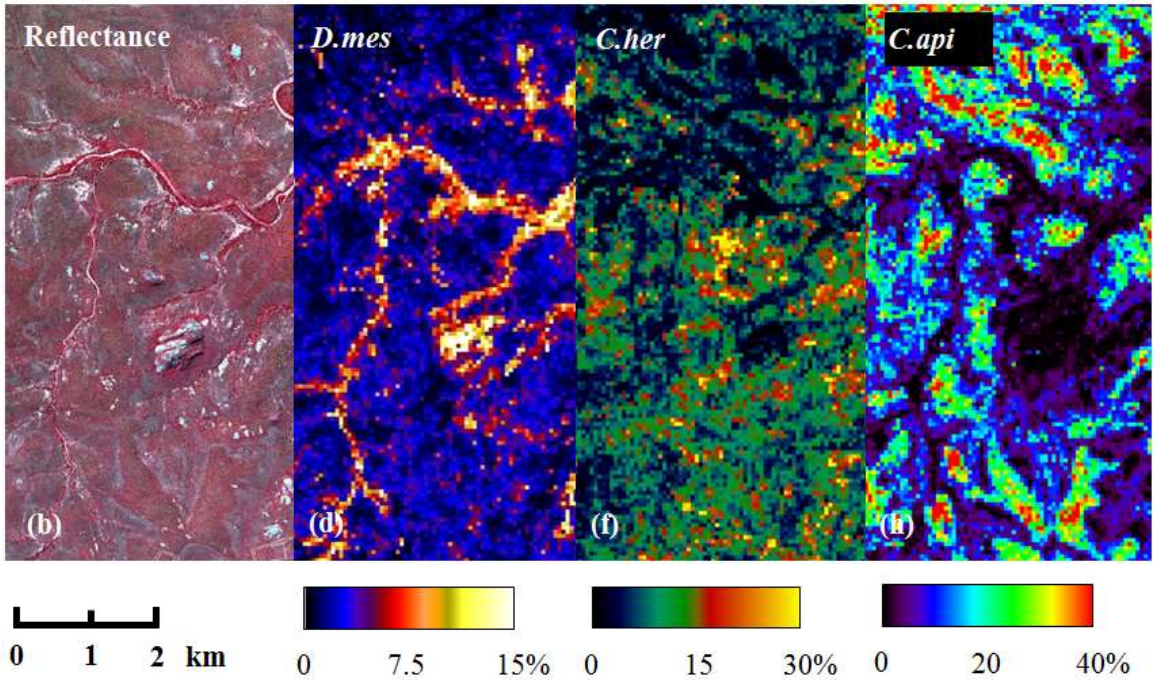
Challenges of remotely sensing plants

- Separation of soil and other non-vegetative components
- Atmospheric effects
- Variable illumination and viewing geometry

Before BRDF correction



After BRDF correction

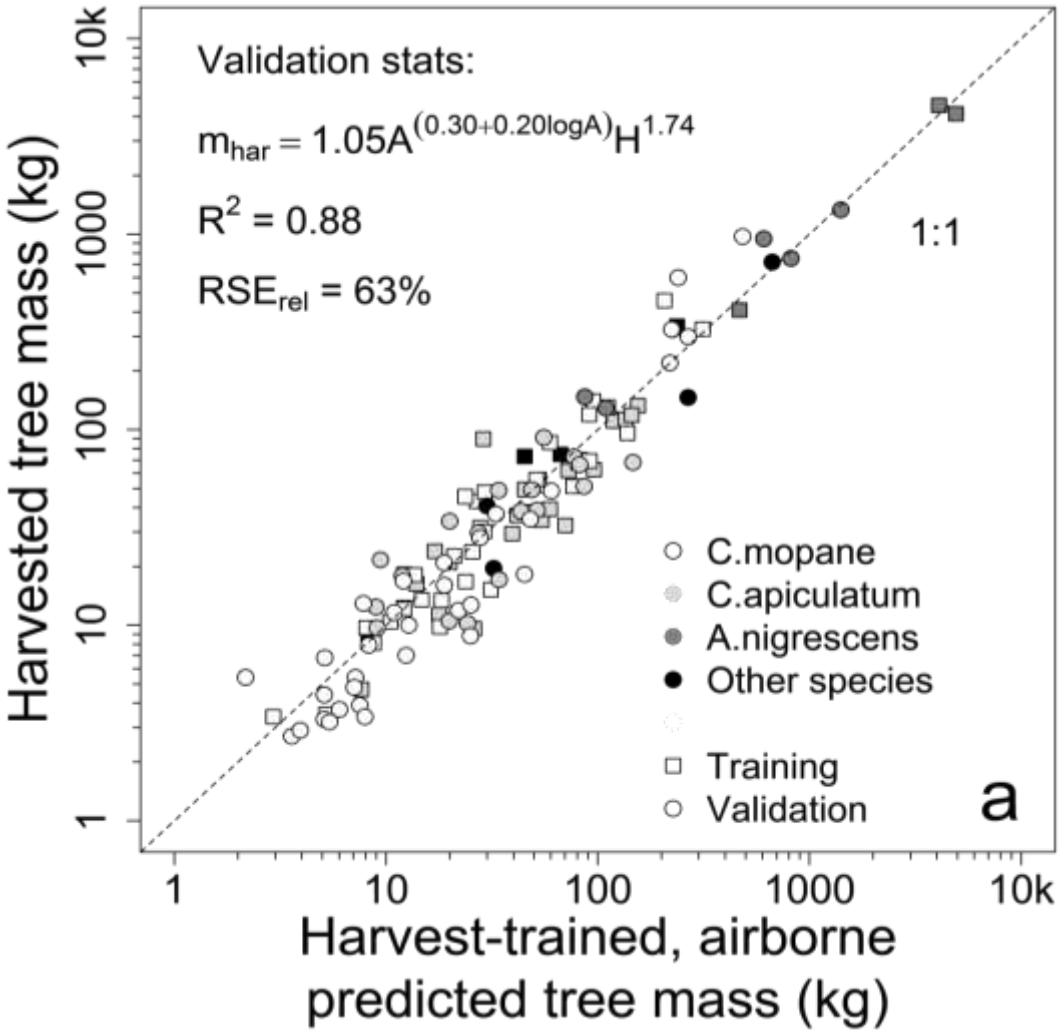


Colgan et al, Remote Sensing, 2013

Example crop traits relevant to biofuels and commonly associated field and remote sensing metrics

Plant trait	Field metric	Remote sensing
Leaf biomass	Harvest, dry, weigh	NDVI, other multispectral
Woody biomass	Allometry + stem D, H	LiDAR height
Leaf nitrogen	Chemical assay SPAD	Multispectral
Leaf water content	Weigh/harvest/ oven-dry/weigh	SWIR hyperspectral

Measuring woody biomass of individual trees using airborne LiDAR



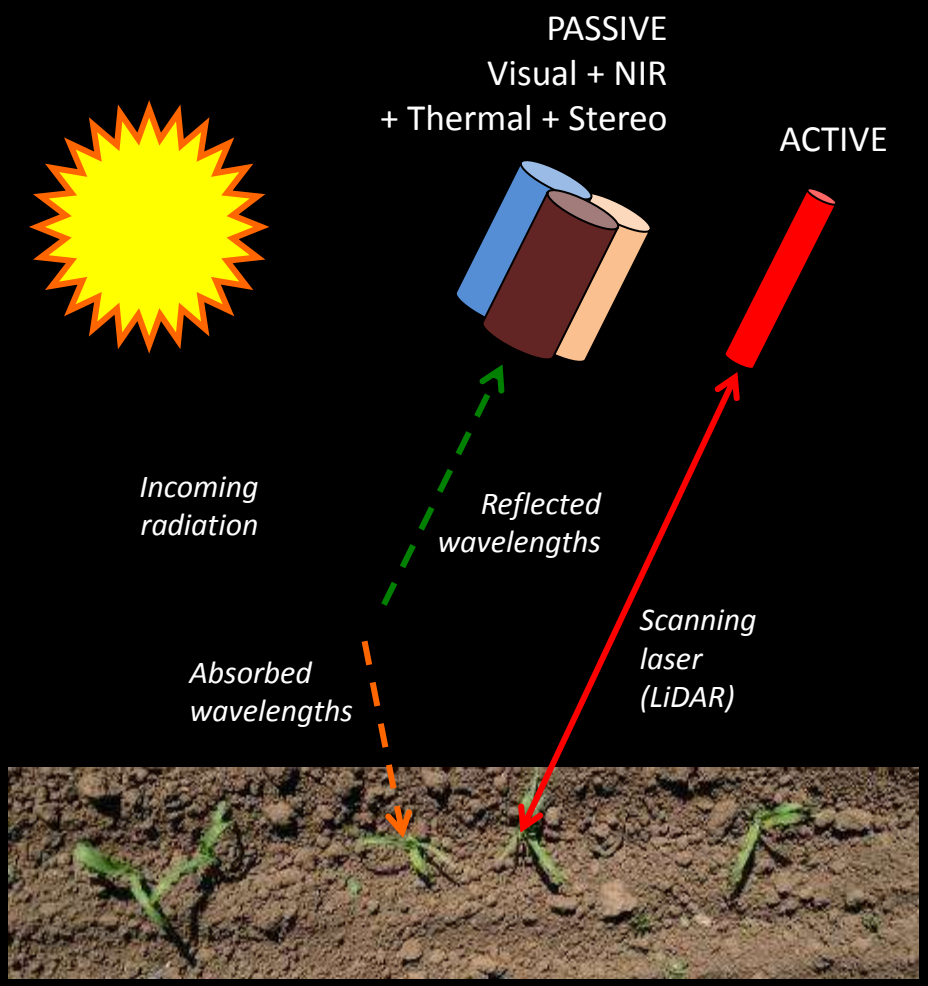
Colgan et al, Ecological Appl, 2013

Wish lists for future crop phenotyping technologies

- Currently challenging / impossible to remotely sense soil moisture, N, P, texture at depth
- Root imaging to better understand how crops partition resources
- Plant-by-plant imaging of breeding trial plots to observe intra-plot variance, improve trait estimation, and enable more plots

Blue River Technology: bringing machine vision & robotics to agriculture

Advanced field-based phenotyping at Blue River Technology: image capture and processing



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